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Application of Cedarwood oil Methyl Ester with Carbon Nano Wires in Marine Engine Studies

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Present study is focused to improve biodiesel from Cedar Wood Oil (CWO) and appraise its effect on the engine performance and emission. Cedarwood is found to be appropriate for biodiesel production on a large scale. CWO extraction was done by combination of expeller and solvent extraction method. Transesterification method was carried out by addition NaOH and methanol to form fatty acid methyl ester of cedarwood oil. Further, experimental investigation was conducted in a single cylinder naturally aspirated direct injection compression ignition engine coupled with eddy current dynamometer. Engine was improved for better performance and reduced emissions.

[**Keywords:** Cedarwood oil, Transesterification, Methyl ester, Performance, emission]

Introduction

Ever since it was known that fossil fuels are finite sources and indeed will only suffice for the next few generations, scientists have been actively looking for alternatives [1]. Recently, there has been a growing interest on biodiesel, an alternative liquid fuel developed from vegetable oils and fats [2]. At present around 10 percent of the vegetable oils being produced are utilised towards non-edible applications and therefore the consumption of vegetable oils for biodiesel will put immense pressure on the food sector. This challenge can be alleviated by the exploration of new crops and unexploited oil crops which are capable of producing oils [3]. Although termed cedarwood oils, the most important oils of this group are produced from distilling wood of a number of different junipers and cypresses, rather than true cedars. A cedar leaf oil is also commercially distilled from the Eastern arborvitae and similar oils are distilled, pressed or chemically extracted in small quantities from wood, roots and leaves from plants of the genera Platycladus, Cupressus, Taiwania and Calocedrus. Cedar oil of the ancients, in particular the Sumerians and Egyptians, was derived from the Cedar of Lebanon, a true cedar native to the northern and western mountains of the Middle East. Non-edible oils are being successfully utilized for the production of biodiesel. CWO being a byproduct can have economic advantages in its use. At present, CWO finds industrial application in very limited fields. In order to consider it as one of the source for biodiesel a detailed investigation was carried out.

Materials and Methods

Extraction of oil from the Cedar wood for the study was carried out by two modes. In the first mode, the extraction of oil was made through a commercial oil expeller. In the second mode, the extraction was made using solvent extraction method. Solvent-Expeller extraction method was employed for the separation of oil from Cedar wood biomass. Hexane and Ether solvents were added to rupture the membrane wall of the oil and released 360 mL of CWO. Extracted oil was kept in the incubator at 80°C for the removal of excess hexane whose boiling point is between 50°C to 70°C and 350 mL of pure CWO was left behind. The process of converting the vegetable, plants and microbial oil into biodiesel is called transesterification. Technically, transesterification refers to neutralizing the free fatty acids, exchanging the triglyceride or a fatty acid molecule into glycerol and alcohol esters in the presence of a catalyst.

During this reaction, the biodiesel occupies the top layer and glycerol is present in the bottom layer as shown in Figure 1. Glycerin is obtained from glycerol and can be used for making soap. The fatty acid methyl ester is carefully separated and washed with 5% distilled water until all the impurities are removed.

Transesterification reaction was carried out using methanol and sodium hydroxide as catalyst. 20% methanol is mixed with 5% sodium hydroxide to form sodium hydroxide to form sodium methoxide along with 350 ml of CWO. The mixture is kept in a rotating agitator for 16 hrs at 200 rpm. Settling period of 24 hrs is allowed for the separation of biodiesel, pigments and glycerol. The formation of glycerol in the bottom layer confirms the transesterification reaction and ester formation. Glycerol is carefully removed using an inverted separator [4]. Transesterification is carried out in two phases (i.e) one by varying the methanol concentration at room temperature and elevated temperature (at 50°C) and the other by varying the concentration of sodium hydroxide. At room temperature, methanol concentration was kept constant and found that the reaction rate was about 50% and 180 ml of CWOME was obtained. Then the temperature was elevated upto 50°C during which the formation of water molecule was very much reduced and the reaction rate was more than 75% during which 240 ml of CWOME was obtained. Methanol content was increased till the molar ratio of 6:1 is attained which resulted in better yield of biodiesel upto 10%. The overall yield of CWOME was found to be 22% (i.e) in an area of 1 square meter, 1.2 kg of cedar wood biomass was obtained which yielded 240 ml of pure CWOME.

Fig. 1 Process involved during biodiesel production

The concentration of sodium hydroxide also played a very major role in the formation of biodiesel. At 50°C, 5% of sodium hydroxide is added to ethanol to form sodium methoxide along with CWO which resulted in formation of more than 90% of FAME's. But when the concentration of NaOH was increased more than 5%, a gelatin layer formation takes place and resulted in reduction of transesterification reaction and further ended up with no significant change in the reaction rate. During the transesterification reaction, it is also noted that, the algal oil contains nearly 10% of free fatty acid. It was known that the presence of FFA's reduces the ester formation to a great extent. Therefore it is reduced to 1% by adding 1% of concentrated sulphuric acid to the CWO during the transesterification reaction [5].

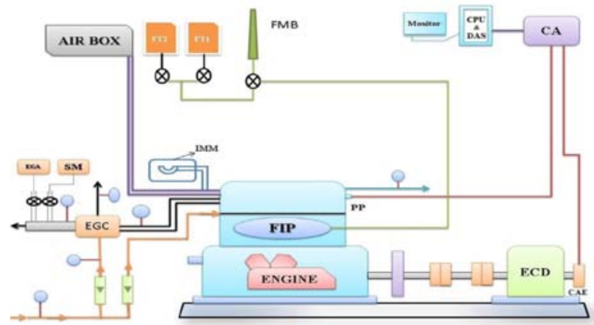


Fig. 2 Schematic Diagram of the experimental test rig

In the present investigation, the tests were conducted on a single cylinder, four stroke, air cooled direct injection diesel. Performance and emission characteristics were obtained for various loads at constant speed of 1500 rpm. Cylinder pressure was measured by mounting a quartz transducer with an inbuilt charge amplifier with a range of 0–100 bar into the cylinder head. The heat release rate was measured by first law analysis of twenty cycles of pressure crank angle data. Cylinder gas pressure data was logged as the average of 20 cycles of data with a resolution of 0.5°CA using a data acquisition system. Power output is tested after the operating temperature reached up to 80°C. Loading is by means of an eddy current dynamometer. Cylinder compression ratio of all the tests is 17.5:1 and the results were noted under steady state conditions. Emissions were measured using an AVL five gas analyzer. CO and CO_2 were measured as percentage volumes but total hydrocarbon was measured as n-hexane equivalent in ppm. NO was calculated in ppm Smoke was measured in terms of percentage opacity using an AVL smoke meter. Experimental set up is shown in Figure 2. The fuel tank is connected with standard burette to measure the quantity of fuel consumed in unit time. Cabon nano wire of average size of less than 50 nm are supplied by the Manufacturer M/s. Sigma-Aldrich. The nanowires are weighed by Digital balance 0.001g accuracy shimadzu make, Model BL220H, 220g capacity. Mixing of carbon nanowires in biodiesel was blended with a neat diesel placed in an ultrasonicator set at a frequency of 40 kHz and 120 W for 60 minutes. Three samples of B20, B20C50 and B20C100 were prepared.

Results

C-NMR Analysis

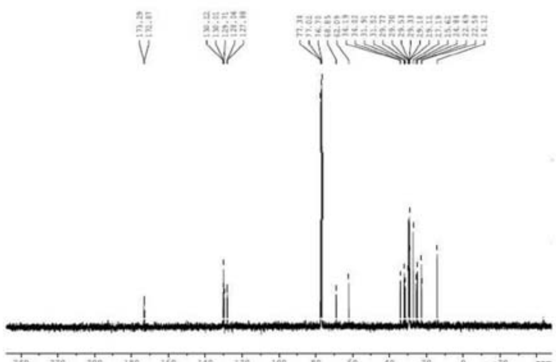


Fig. 3 ^{13}C-NMR spectra of CWO

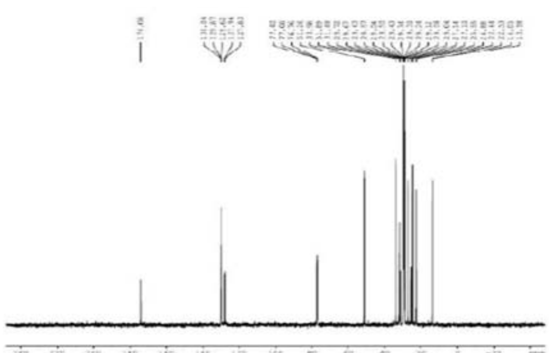
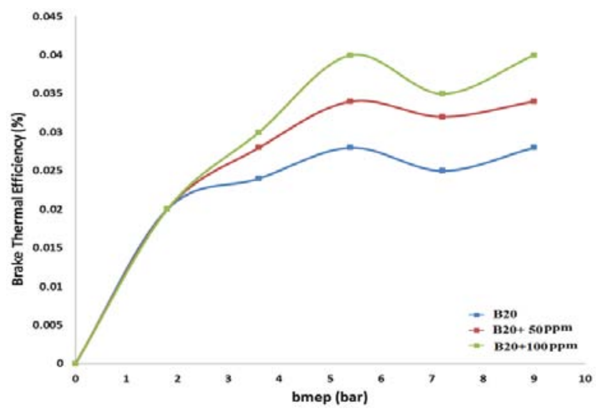


Figure 4. ^{13}C-NMR spectra of CWOME

The ^{13}C NMR spectrum of the CWO and CWOME is shown in Figure 3 and Figure 4 respectively, which show the characteristic peaks of C-O and ester carbonyl (-COO-) at 51.28 and 174.16 pm respectivelyFrom Figure 3, the disappearance of signal at 63 and 69 ppm and the appearance of a new signal at 52 ppm is due to CH2 carbon in the prepared biodiesel. The signals of the ester group carbon are located at approximately 174 ppm. From Figure 4, the signals identified at 23 to 33 ppm are attributed to methylene carbons of long carbon chain in fatty acid methyl esters. The unsaturated carbon presents between 128 and 131 ppm. From Figure 4, the signals at 175 ppm and 52 ppm confirm the success of the transesterification reaction. In addition to this, various signals correspond to the internal CH2, have been observed between 23 and 35 ppm as shown in Figure 3 and Figure 4.

Performance charactersitcs

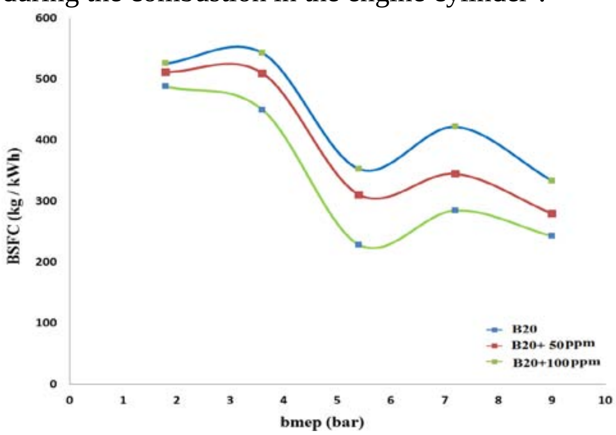


Figue 5. Variation in brake thermal efficiency with bmep

The variation in brake thermal efficiency with bmep of all test fuels is shown in the Fig. 5. Brake thermal efficiency of the engine is developed by the addition of carbon Nano Wires in the blends. Carbon nano wires present in the blend promote longer and more complete combustion and also acts as an oxygen buffer, thus increasing the efficiency. It has also been identified that the improvement in the efficiency generally increases with the dosing level of nano wires. This could be possibly attributed to improved combustion characteristics of nano wires, such as advanced surface area volume ratio, which, in turn, allows more amount of fuel to react with the air leading to improvement in the brake thermal efficiency [6].

The variation of Brake Specific Fuel Consumption (BSFC) with bmep of all test blends is shown in the

Fig.6. BSFC reduces with an increase in the dosing level of carbon nano wires. It is observed that more quantity of fuel has been consumed to maintain the engine speed constant. This could be possibly attributed to the presence of nano wires in the blend as it possess enhanced surface area–volume ratio for better the catalytic effect and less fuel consumption during the combustion in the engine cylinder[7].



Figue 6. Variation in BSFC with bmep

Emission characterstics

The variation of CO and HC emissions with bmep for B20, B20C50 and B20C100 blends has been shown in the Fig.7&8. CO emission critically depends on the air-to-fuel ratio relative to stoichiometries proportions. Generally, compression ignition engines work with a lean mixture, and hence CO emissions would be lower. Incomplete mixing of fuel with air and reducing of the oxidation process are the main sources of HC emissions in diesel engine. The CO and HC emissions for the carbon nanowires blends are lower. This could be possibly attributed to the enriched ignition characteristics of carbon nanowires leading to high catalytic activity due to their higher surface to volume ratio and improving fuel air mixing in the combustion chamber [8].

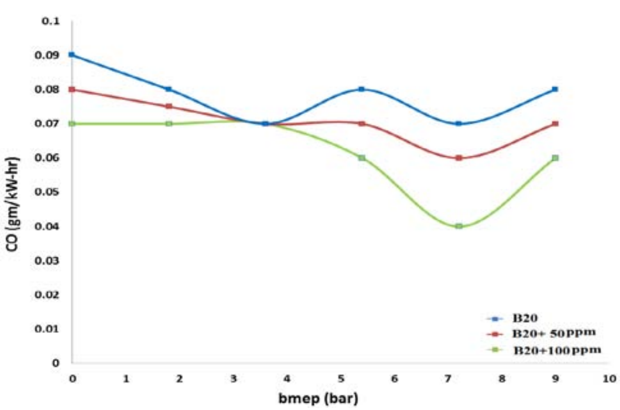
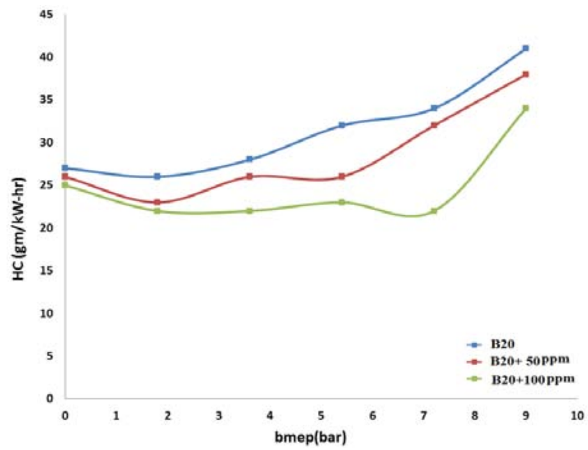
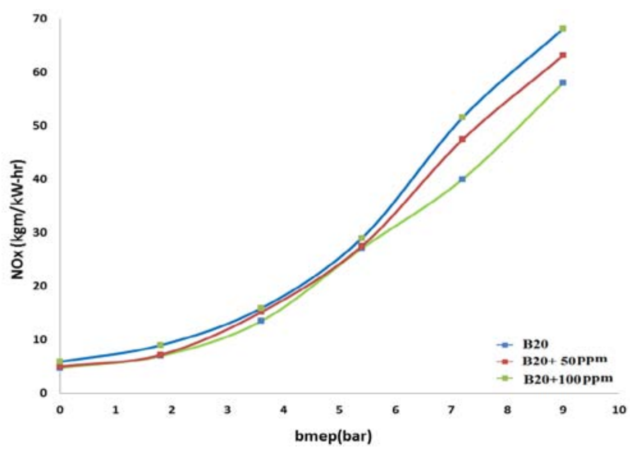


Figure 7. Variation in CO with bmep

The variation of NOx emissions with bmep for B20, B20C50 and B20C100 blends has been shown in the Fig.9. According to the Zeldovich mechanism, the formation of NOx is dependent on residence time, oxygen concentration and temperature. Oxygen contents and combustion temperature could be higher for B20, leading to the higher NOx emissions. This is due to the shortened ignition delay, quick evaporation rate and improved ignition characteristics of carbon nanowires [9].



Figue 8. Variation in HC with bmep



Figue 9. Variation in NOx with bmep

Conclusion

The studies on performance and emission characteristics of a CWOME blended with carbon nanowires is performed by a four stroke single cylinder, naturally aspirated, water cooled, direct injection diesel engineunder different operating condition. Biodiesel was produced through the chemical transesterification of cedarwood biomass. The conversion of methyl ester is confirmed by ^{13}C-NMR spectroscopy method. Based on the result the following conclusions were drawn:

- Decrease in BSFC can be due to the positive effects of nanowires on physical properties of fuel and also reduction of the ignition delay time.
- Combustion characteristics improved by the lighter surface – area – to- volume ratio of nano wires which is allowed more amount of fuel to react with air. It leads to enhancing in BTE.
- The CO and HC are appreciably reduced with the addition of carbon nanowires.
- The NOx emission is also found to be less for carbon nanowires added blends.

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